Louisiana Coastal Protection and Restoration Project

Sea-Level Change Issues

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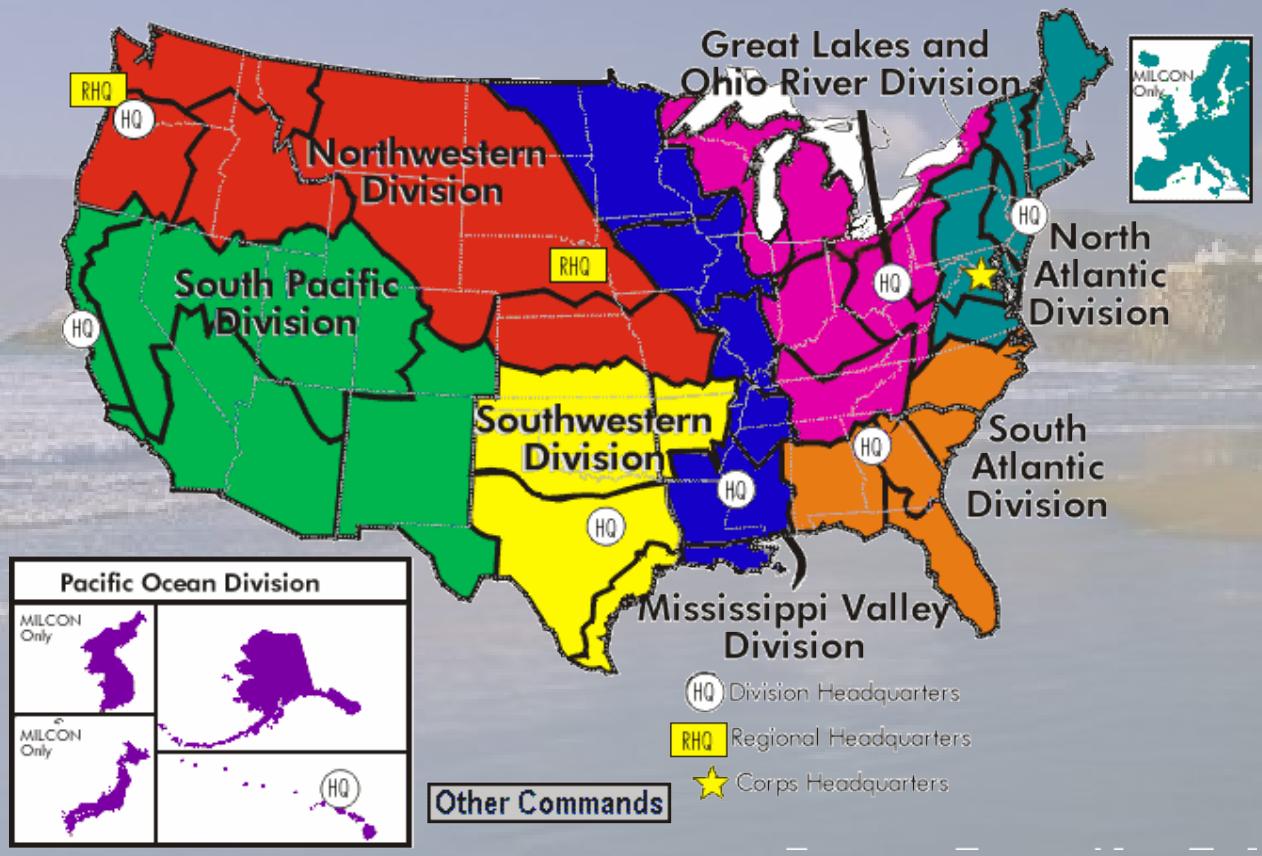
USACE Districts



41 total districts

22 coastal districts

Even small coastal districts have large financial interest in SLR (eg – SPN had $60 million in 2002)

Sea Level Change

- Eustatic rise **(accelerating?)**
  - EPA estimated 340 mm by 2100 (1.1 ft/cnty) with 10% chance of 650 mm by 2100 (2.1 ft/cnty)[1]
  - NRC estimates 500-1500 mm by 2100 (1.6-4.9 ft/cnty)[2]
- Relative change
  - San Diego (941 0170) ~ +2.15±0.12 mm/year (0.71 ft/cnty)[3]
  - Juneau (945 2210) ~ -12.69±0.26 mm/year (-4.2 ft/cnty)[3]

1 *The Probability of Sea Level Rise*, (EPA, 1995)
2 *Responding to Changes in Sea Level: Engineering Implications*, (NRC, 1987)
3 NOAA Technical Report, *Sea Level Variations in the United States, 1854-1999* (Zervas)

Sea Level Change

(local variations)*

- San Francisco (941 4290)
  - 1.41±0.08 mm/yr (0.46 ft/cnty) 1854-1999
  - 1.12±0.35 mm/yr (0.37 ft/cnty) 1854-1906 (pre EQ)
  - 2.13±0.14 mm/yr (0.70 ft/cnty) 1906-1999 (post EQ)
- Alameda (941 4750)
  - 0.89±0.32 mm/yr (0.29 ft/cnty) 1939-1999

* NOAA Technical Report, *Sea Level Variations in the United States, 1854-1999* (Zervas)

USACE Policy

- 1986 – local historical data with extrapolation
- 2000*
  - Addresses the risk and uncertainty associated with both historically determined and future estimates for sea level rise rates.
  - Applies to “every coastal and estuarine (as far inland as the new head of tide) feasibility study that the Corps undertakes.”

* Engineering Regulation 1105-2-100, *Planning Guidance* (USACE, 2000) (Appendix E, Section IV.E-24.k)

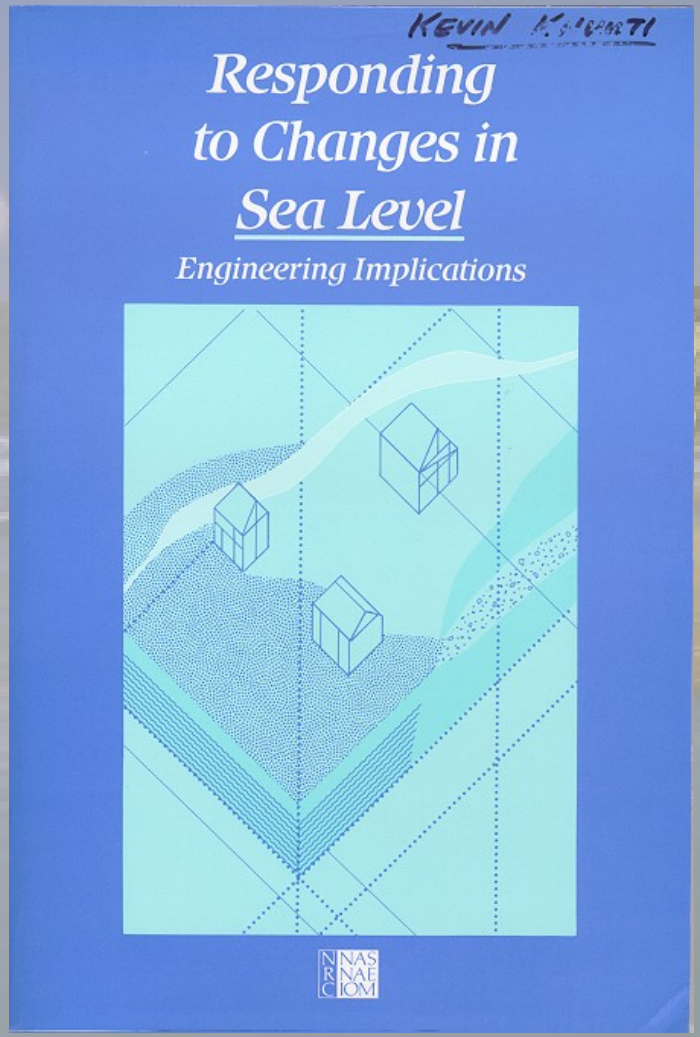
USACE Policy

(eustatic sea level rise)

National Research Council, 1987.

Responding to Changes in Sea Level: Engineering Implications.

National Academy Press.



USACE Policy

Engineering Regulation **1105-2-100**, *Planning Guidance*

(Appendix E, Section IV.E-24.k)

- *A sensitivity analysis should be conducted to determine what effect (if any) changes in sea level would have on plan evaluation and selection. The analysis should be based, as a minimum, on the extrapolation of the local, historical record of relative sea level rise as the low level and Curve 3 from the NRC report as the high level*

- *If the plan selection is sensitive to sea level rise, then design considerations could allow for future modification when the impacts of future sea level rise can be confirmed* [adaptive management].

- *Feasibility studies should consider which designs are most appropriate for a range of possible future rates of rise. Designs that would be appropriate for the entire range of uncertainty should receive preference over those that would be optimal for a particular rate of rise but unsuccessful for other possible outcomes.*

USACE Policy

Three methods to incorporate SLR into CoE projects

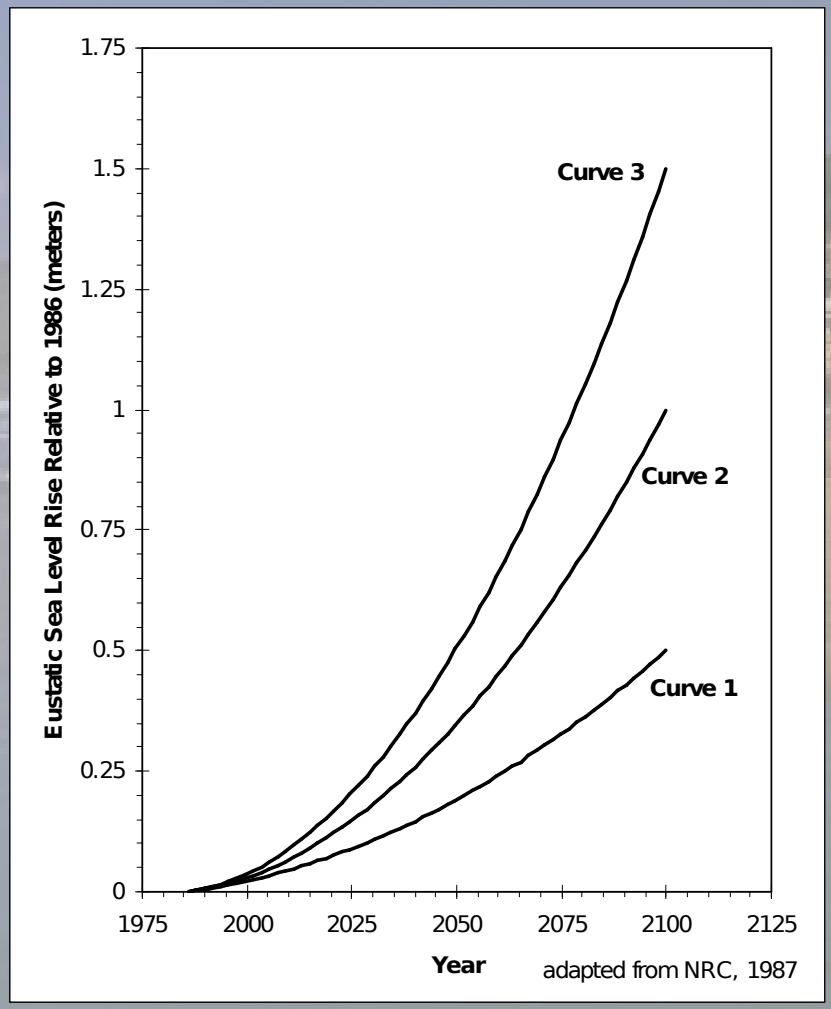
1. Adaptive management
2. Facilitating future modifications
3. Design for the future

USACE Policy
(lower and upper bounds)

- Local historic rate
- NRC rate(s)

  $E(t) = 0.0012t + bt^2$

  - Curve 3
    (1.5 m, b = 1.069E-4)
  - Curve 2
    (1.0 m, b = 6.770E-5)
  - Curve 1
    (0.5 m, b = 2.854E-5)



USACE Practice

Not standardized throughout the Corps

- 1986 policy in some areas
- 2000 policy in some areas
- Not addressed at all in many areas

USACE Practice
(2000 policy)

- Lower and upper bounds for SLR
  - Lower bound (historic rate) = 2.13 mm/year (0.107 m over 50-year project life)
  - Upper bound (NRC, Curve 3)

$$E_3(t_2) - E_3(t_1) = 0.0012(t_2 - t_1) + b(t_2^2 - t_1^2)$$

t_1 = start year – 1986

$t_2 = t_1 + 50$

$E_3(t) = 0.49$ meters

- Intermediate values

$E_2(t) = 0.33$ meters

$E_1(t) = 0.17$ meters

USACE Practice
(2000 policy)

- Hard structures – 3-step procedure
  - Sensitive to SLR?
  - 3 methods
    - » Adaptive management
    - » Facilitating future modifications
    - » Design for the future
  - Evaluate for range of SLR and calculate benefit:cost ratio
  - Preference given to most successful design over full range of SLR
- Soft “structures” (eg., beach fill) – additional (intermediate) step of evaluating erosion/transport annually over life of project

USACE Practice

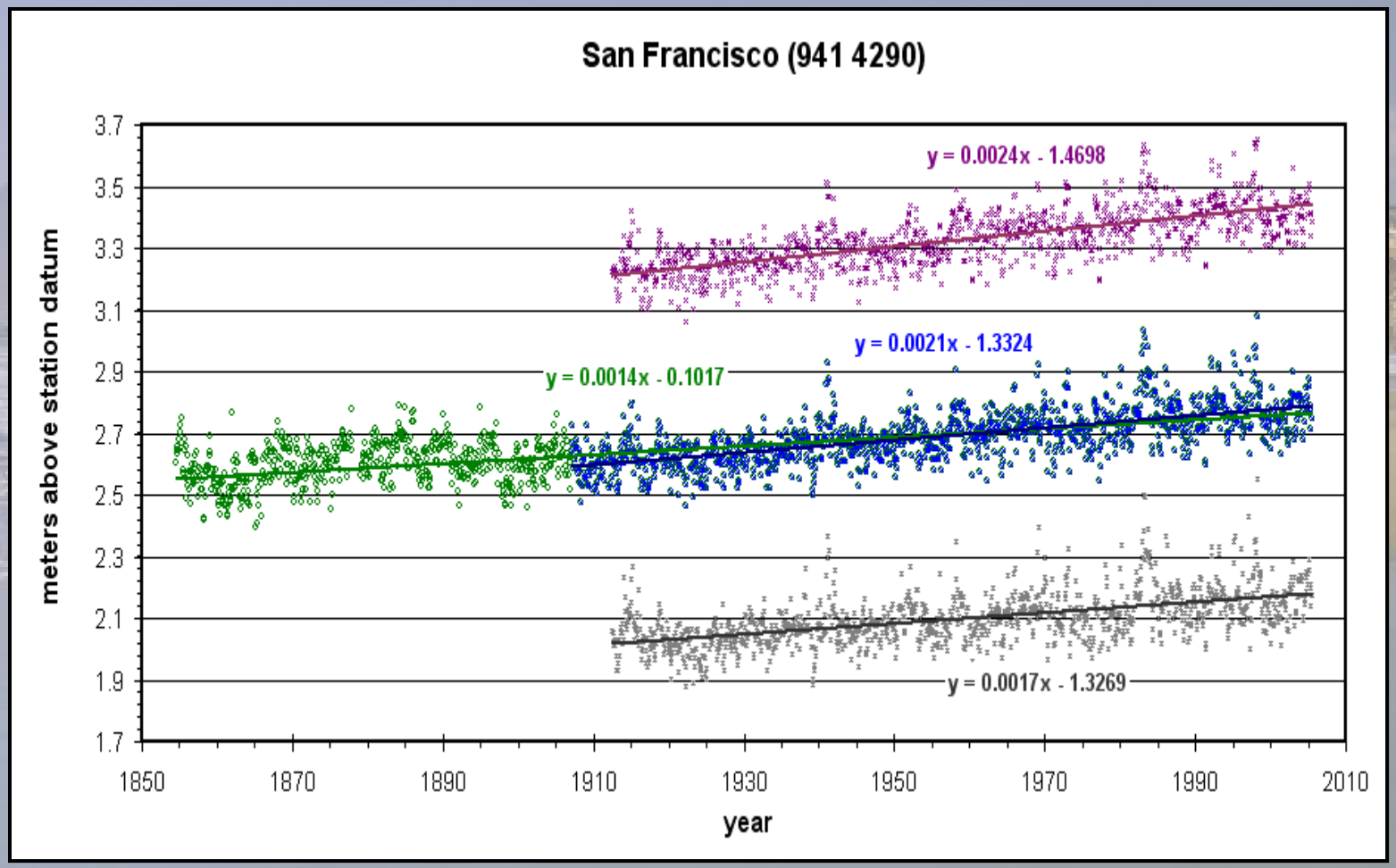
2000 (current) policy

Example table

Alternative evaluations for varying rates of local mean sea level rise

	Accommodates Sea Level Rise/Benefit:Cost Ratio			
Alternative	Historical rate*	Curve 1 rate*	Curve 2 rate*	Curve 3 rate*
1(a) Revetment (adaptive mgmnt)	Yes / 1.40:1	Yes / 1.38:1	Yes / 1.19:1	Yes / 1.02:1
1(b) Revetment (facilitates future modifications)	Yes / 1.23:1	Yes / 1.09:1	No / 0.99:1	No / n/a
1(c) Revetment (designed for 50-year sea level rise value)	Yes / 1.27:1	Yes / 1.17:1	Yes / 1.03:1	No / 0.92:1
2(a) Seawall 1				
2(b) Seawall 1				
2(c) Seawall 1				
3(a) Seawall 2				
3(b) Seawall 2				
3(c) Seawall 2				
4(a) Beach nourishment				
4(b) Beach nourishment				
4(c) Beach nourishment				
5(a) Dune nourishment				
5(b) Dune nourishment				
5(c) Dune nourishment				
6 No action				

Other Considerations



LMSL Trend

duration

0.0014 m/yr or

0.46 ft/century

Post-eq

0.0021 m/yr or

0.69 ft/century

MHW Trend

0.0024 m/yr or

0.79 ft/century

MTR Trend

increasing

Other Considerations

- **MSL vs MHW vs . . . ?**
  - **San Francisco LMSL ~ 1.4 mm/yr (0.46 ft/cnty)**
  - **San Francisco LMSL (post EQ) ~ 2.1 mm/yr (0.69 ft/cnty)**
  - **San Francisco MHW ~ 2.4 mm/yr (0.79 ft/cnty)**
  - **San Francisco MLW ~ 1.7 mm/yr (0.56 ft/cnty)**
- **Updated estimates for eustatic SLR**

Louisiana
Local Mean Sea Level Changes

Table XX. Linear RLMSL trends for monthly data up to 1999					
Station Name	**First Year**	**Year Range**	**MSL Trend and Standard Error (mm/yr)**		**Standard Error of Model (mm)**
Grand Isle	**1947**	**53**	**9.85**	**0.35**	**51.0**
Eugene Island	**1939**	**36**	**9.74**	**0.63**	**52.8**
Sabine Pass	**1958**	**42**	**6.54**	**0.72**	**72.6**

These trends show a maximum historic RLMSL rise rate of 9.85 $\pm$ 0.35 mm/year (3.23 $\pm$ 0.11 ft/century) for southern Louisiana, based on historic tide records at these three tide gauges.

Table XX. Eustatic MSL rise between 2006 and various future years, based on 1987 NRC report

Year	Years from 2006	Eustatic MSL (meters)		
		Curve 1	Curve 2	Curve 3
2011	5	0.0124	0.0212	0.0301
2016	10	0.0263	0.0459	0.0655
2021	15	0.0415	0.0739	0.1062
2026	20	0.0582	0.1052	0.1523
2031	25	0.0764	0.1400	0.2037
2036	30	0.0959	0.1782	0.2605
2041	35	0.1169	0.2197	0.3226
2046	40	0.1393	0.2646	0.3901
2051	45	0.1632	0.3130	0.4629
2056	50	0.1884	0.3647	0.5411
2061	55	0.2151	0.4197	0.6246
2066	60	0.2432	0.4782	0.7134
2071	65	0.2728	0.5401	0.8076
2076	70	0.3038	0.6053	0.9071
2081	75	0.3362	0.6739	1.0120
2086	80	0.3700	0.7459	1.1222
2091	85	0.4052	0.8213	1.2378
2096	90	0.4419	0.9001	1.3587
2101	95	0.4800	0.9823	1.4850
2106	100	0.5196	1.0678	1.6166

References

for RMSL Change

- National Research Council, 1987. *Responding to Changes in Sea Level: Engineering Implications.* National Academy Press.
- USACE Planning Guidance (2000):

  http://www.usace.army.mil/inet/usace-docs/eng-regs/er1105-2-100/toc.htm
- Zervas, Chris, 2001. Sea Level Variations of the United States, 1854-1999. NOAA Technical Report.
- Knuuti, Kevin, 2002. *Planning for Sea-Level Rise: U.S. Army Corps of Engineers Policy.* Solutions to Coastal Disasters '02.
- Knuuti, Kevin, (awaiting publication). *Applications of Tidal Datum Trends in Coastal Engineering.*
- Flick, Reinhard et. al., 1999. *Trends in U.S. Tidal Datum Statistics and Tide Range: A Data Report Atlas.* SIO Ref. Series No. 99-20.